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Characterization of Cavities Using the GPR, LIDAR and GNSS Techniques

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Abstract—The study of the many types of natural and manmade cavities in different parts of the world is important to the fields of geology, geophysics, engineering, architectures, agriculture, heritages and landscape. Ground-penetrating radar (GPR) is a noninvasive geodetection and geolocation technique suitable for accurately determining buried structures. This technique requires knowing the propagation velocity of electromagnetic waves (EM velocity) in the medium. We propose a method for calibrating the EM velocity using the integration of laser imaging detection and ranging (LIDAR) and GPR techniques using the Global Navigation Satellite System (GNSS) as support for geolocation. Once the EM velocity is known and the GPR profiles have been properly processed and migrated, they will also show the hidden cavities and the old hidden structures from the cellar. In this article, we present a complete study of the joint use of the GPR, LIDAR and GNSS techniques in the characterization of cavities. We apply this methodology to study underground cavities in a group of wine cellars located in Atauta (Soria, Spain). The results serve to identify construction elements that form the cavity and group of cavities or cellars. The described methodology could be applied to other shallow underground structures with surface connection, where LIDAR and GPR profiles could be joined, as, for example, in archaeological cavities, sewerage systems, drainpipes, etc.

Key words: Cavities, underground cellars, GNSS, LIDAR, GPR, geodetection.

1. Introduction

The study of the different types of natural and manmade cavities is important to the fields of geology, geophysics, engineering, architecture, agriculture, heritages and landscapes (López-Geta 2002; Deparis et al. 2008; Jol 2009; Pettinelli *et al.* 2011). Geodetection is a noninvasive technique that is suitable for the accurate location of buried structures underground. Traditionally, this kind of underground cavity is characterized by topographic work, normally using laser imaging detection and ranging (LIDAR) techniques. As these techniques do not detect hidden structures, ground-penetrating radar (GPR) has also been used in cavity characterization by different authors. We add the integration of LIDAR with GPR data, joined by Global Navigation Satellite System (GNSS) positioning, to achieve the characterization of structures not detected by LIDAR.

GPR systems work by propagating a radio wave through the ground. The propagation characteristics of the ground medium determine the propagation velocity of the electromagnetic wave (EM velocity) and its attenuation as the wave propagates. Except for a few magnetic minerals, propagation in most ground media depends mainly on their electrical properties (e.g., Lorenzo 1996; Reppert and Morgan 2000; Lapazaran 2004). Laser scanning is also a suitable measuring technique for monitoring the deformations of certain structures over time to ensure structural safety and guarantee the control of the structure (Keumsuk *et al.* 2007; Burns *et al.* 2012).

The most commonly used techniques in geomorphology are GPR, seismic refraction and direct current (DC) electrical resistivity. These techniques are useful in answering unanswered questions in geomorphological research regarding the thickness of

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